Plasmonics: Chip-Based Component Devices and Metamaterials

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Abstract: Dispersion control and active materials integration have yielded plasmonic components including i) three-dimensional single layer plasmonic metamaterials ii) all-optical, electro-optic and field effect modulation of plasmon propagation iii) plasmon-enhanced absorption in solar cells.

OCIS codes: (160.3918) Metamaterials; (250.3140) Integrated optoelectronic circuits

1. Introduction

Plasmonics has provided nanoscience researchers new control of optical dispersion and light localization at nanoscale dimensions. Plasmonic design approaches are yielding new metamaterials designs and also the building blocks for chip-based optical component device technology with potential imaging, spectroscopy and interconnection applications in ultramicroscopy, computing, communication and chemical/biological detection.

2. Plasmonic Metamaterials

We expand upon recently reported work on direct observation of two-dimensional negative refraction in the visible frequency range[1] to develop a general approach to realization of three-dimensional single-layer, all-angle, polarization-independent plasmonic metamaterials exhibiting negative refraction. Full wave simulations and the extraction of the mode-effective permittivity and permeability from experiments across the negative refraction regime and show that both are negative.

3. Modulators

Metal-dielectric plasmon waveguides can serve as active switching elements when the dielectric refractive index can be actively modulated. We demonstrate all-plasmonic modulation in which the complex mode refractive index seen by a surface plasmon polariton at infrared free-space wavelength (λ = 1.42 μm) is modulated via interband excitation of the dielectric medium at visible frequencies (λ = 0.514 μm) [2]. We also demonstrate electro-optic refractive index modulation in metal-dielectric-metal plasmon waveguides using low-voltage electro-optic modulation of both silicon and perovskites oxide dielectric layers. Finally, we also demonstrate field effect modulation of the complex refactive mode index for plasmonic modes propagating in the channel of a silicon MOS field effect device.

4. Photovoltaics

The efficiency and cost effectiveness of photovoltaic cells can both be increased by reduction of the active semiconductor absorber layer thickness and ability to fabricate ultrathin absorber layers opens up new possibilities for solar cell device design. The strong mode localization of surface plasmon polaritons at metal-dielectric interfaces leads to strong absorption in semiconductors thin films, enabling a dramatic (10-100X) reduction in the semiconductor absorber physical thickness needed to achieve an optically thick film. Modal analysis in full wave simulation allows us to determine the fraction of power absorbed by the solar cell to be determined for both dielectric and plasmonic modes.

[1] HJ. Lezec, J.A. Dionne, H.A. Atwater, Science 316 430 (2007)
[2] D. Pacifici, HJ. Lezec, and, H.A. Atwater, Nature Photonics 1 402 (2007).

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